

[illegible][illegible]

*(The following musical score is transcribed from the image, showing staves for Soprano, Alto, Tenor, and Bass parts.)*

Soprano Cantata No. 1 Op. 10 1897	Alto Cantata No. 2 Op. 10 1897	Tenor Cantata No. 3 Op. 10 1897	Bass Cantata No. 4 Op. 10 1897
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1     TITLE OF THE INVENTION

          MOUNTING METHOD OF SEMICONDUCTOR DEVICE

BACKGROUND OF THE INVENTION

5           (1) Field of the Invention

          The present invention generally relates to a mounting method of a semiconductor device, and more particularly to a method of mounting a semiconductor device on a board in accordance with a COB (Chip On Board) method.

10          (2) Description of the Related Art

          V various methods have been proposed as the COB (Chip On Board) method of mounting a semiconductor device on a board, based on purposes and uses of the semiconductor device. A flip-chip mounting method is one of the methods proposed as the COB method. In this mounting method, a semiconductor device (a semiconductor chip) is directly mounted on a board without wires connecting the semiconductor device to the board. The flip-chip mounting method is also called a wireless bonding mounting method.

          A description will be given, with reference to Figs. 1A through 1F, of the flip-chip mounting method.

25          Pads 2, which are electrodes, are formed on a chip 1 (the semiconductor device) to be mounted on a board 3. Pads 4 which are parts of conductive wiring patterns are formed on the board 3 on which the chip 1 is to be mounted.

30          First, bumps are formed as shown in Fig. 1A. Referring to Fig. 1A, an end portion of a gold wire 5 is pressed on a pad 2 of the chip 1 and heated by a bonding tool so as to be joined to the pad 2. In this state, the gold wire 5 is then removed. As a result, 35     a tear-drop shaped bump 6 is formed on the pad 2. On all the pads 2 of the chip 1, tear-drop shaped bumps 6 are formed in the same manner as that describe above.

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1           Next, the tear-drop shaped bumps 6 are  
flattened as shown in Fig. 1B. Referring to Fig. 1B,  
the tear-drop shaped bumps 6 are pressed on a flat  
plate 7 so that only a point end portion of each of  
5   the tear-drop shaped bumps 6 is subjected to the  
plastic deformation. As a result, the tear-drop  
shaped bumps 6 are shaped into bumps 6 having  
substantially the same height.

          Conductive paste is then transferred to a  
10   surface of each of the bumps 6 as shown in Figs. 1C  
and 1D. That is, the end portions of the bumps 6 are  
immersed in a layer of conductive paste 8 as shown in  
Fig. 1C and then pulled up therefrom as shown in Fig.  
1D. As a result, a drop of the conductive paste 8 is  
15   adhered to the end portion of each of the bumps 6.  
The conductive paste 8 is made, for example, of epoxy  
resin in which a large amount of silver fillers are  
distributed. Due to the drop of the conductive paste  
8, positive electrical conductivity can be maintained  
20   between each of the bumps 6 of the chip 1 and a  
corresponding one of the pads 4 of the board 3 when  
the chip 1 is mounted on the board 3.

          Next, adhesive 9 is applied to or printed on  
the surface of the board 3 so that the pads 4 are  
25   covered with the adhesive 9 as shown in Fig. 1E. A  
thermosetting insulating adhesive, made of material  
including epoxy resin as the principal ingredient, is  
used as the adhesive 9 to be applied to the board 3.  
In a state where the chip 1 is mounted on the board 3,  
30   the space between the chip 1 and the board is filled  
with the adhesive 9. As a result, the chip 1 and the  
board 3 are tightly joined to each other. In  
addition, a connecting portion in which each of the  
bumps 6 are joined to a corresponding one of the pads  
35   4 is covered with the adhesive 9, so that moisture is  
prevented from entering the connection portion by the  
adhesive 9.

1 Finally, the chip 1 is mounted on the board  
3 as shown in Fig. 1F. Referring to Fig. 1F, the chip  
1 is positioned so that each of the bumps 6 of the  
chip 1 corresponds to one of the pads 4 of the board  
5 3. A thermopressing head then presses the chip 1 on  
the board 3, so that each of the bumps 6 is pressed on  
a corresponding one of the pads 4 of the board 3. The  
adhesive 9 and the conductive paste 8 are thus  
hardened by the heat, so that the chip 1 is completely  
10 mounted on the board 3.

The board on which semiconductor devices are  
mounted is set and used in electronic equipment, such  
as a personal computer. Due to the heat generated by  
the semiconductor devices on the board, the interior  
15 of such electronic equipment is at a high temperature.  
Particularly, in a case where a processor operated at  
a high frequency is included in the semiconductor  
device, a large amount of heat is generated. On the  
other hand, in a case where the electronic equipment  
20 is not used, that is, a power supply of the electronic  
equipment is in an off-state, the interior temperature  
of the electronic equipment decreases to a room  
temperature.

The interior temperature variation of the  
25 electronic equipment affects the connecting portion in  
which each of the semiconductor devices and the board  
are connected to each other as follows.

As shown in Fig. 2, due to the temperature  
variation, the adhesive 9 between the semiconductor  
30 device 1 (the chip) and the board 3 is thermally  
expanded and contracted, so that the volume of the  
adhesive 9 is varies. Of course, thermal expansion  
and contraction occurs in the board 3, the  
semiconductor device 1 and the bumps 6. However the  
35 rate of expansion (contraction) thereof is less than  
that of expansion of the adhesive 9. Thus, in a case  
where the temperature is increased, the volume of the

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1 adhesive 9 is increased and the increase of the volume  
of the adhesive 9 functions as a force to increase the  
distance between the board 3 and the semiconductor  
device. As a result, a contact force of the bumps 6  
5 to the pads 4 of the board 3 is decreased, so that an  
electric contact resistance between each of the bumps  
6 and a corresponding one of the pads 4 is increased.

Further, when the temperature is repeatedly  
increased and decreased, the electrical contact  
10 resistance is successively increased and finally a  
disconnection may occur between the bumps 6 and the  
pads 4.

#### SUMMARY OF THE INVENTION

15 Accordingly, a general object of the present  
invention is to provide a novel and useful mounting  
method of a semiconductor device in which the  
disadvantages of the aforementioned prior art are  
eliminated.

20 A specific object of the present invention  
is to provide a method of mounting a semiconductor  
device on a board so that even if the volume of  
adhesive between the semiconductor device and the  
board is varied by the variation of temperature, an  
25 increase of the electrical contact resistance of the  
semiconductor device to the board can be prevented.

The above objects of the present invention  
are achieved by a method of mounting a semiconductor  
device including bumps, on a board having pads, so  
30 that each of said bumps is joined to a corresponding  
one of said pads, an adhesive to be hardened by heat  
being provided between said semiconductor device and  
said board, said method comprising the steps of:  
pressing said bumps of said semiconductor device on  
35 said pads of said board; and heating a portion in  
which each of said bumps and a corresponding one of  
said pads is in contact with each other, wherein a

1 pressure of said bumps to said pads reaches a  
predetermined value before a temperature of said  
adhesive to which heat is supplied in step (b) reaches  
a hardening temperature at which said adhesive is  
5 hardened.

According to the present invention, since  
the bumps are pressed on the pads with a pressing  
force of a predetermined value before the adhesive is  
completely hardened, the bumps can be securely joined  
10 to the pads so as to provide a sufficient contact  
area. Thus, even if the hardened adhesive is expanded  
and contracted by the variation of temperature, the  
electrical contact between the bumps and the pads can  
be maintained.

15

#### BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of  
the present invention will be apparent from the  
following description when read in conjunction with  
20 the accompanying drawings, in which:

Figs. 1A through 1F are diagrams  
illustrating a procedure of mounting a semiconductor  
device on a board;

Fig. 2 is a cross sectional view showing a  
25 connecting portion in which the semiconductor device  
and the board are connected to each other;

Fig. 3 is a diagram illustrating a  
relationship between the board and the semiconductor  
device supported by a head used in a thermopressing  
30 step;

Fig. 4 is a timing chart illustrating a  
variation of contact pressure of a bump to a pad and a  
variation of adhering temperature;

Fig. 5 is a characteristic diagram  
35 illustrating a variation of contact resistance to  
a variation of contact pressure between gold (Au) and  
copper (Cu);

1           Fig. 6 is a diagram illustrating an example  
of a chip mounting machine;

          Fig. 7 is a diagram illustrating a polyimide  
film set between the head and the chip in the  
5   thermopressing step; and

          Fig. 8 is a diagram illustrating a variation  
of a pressing force of the head to the chip and a  
variation of the temperature of the adhesive.

10   DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

          A description will be given, with reference  
to Figs. 3 through 5, of a mounting method according  
to an embodiment of the present invention.

          Referring to Fig. 3, a chip 31 (the  
15   semiconductor device to be mounted) is supported by a  
thermopressing head 30. The chip 31 is mounted on a  
board 33 by an operation of the thermopressing head  
30.

          The thermopressing head 30 is movable in  
20   directions indicated by arrows in Fig. 3 and provided  
with a heater 301 and a vacuum cavity 302. The heater  
301 is supplied with an electric current from a power  
supply. The heater 301 generates an amount of heat  
sufficient to warm up adhesive 39 (which will be  
25   described later) to a temperature needed to harden the  
adhesive 39. The vacuum cavity 302 is connected to a  
vacuum system (not shown) so as to support the chip 31  
by a suction force of the vacuum.

          A bump 36 made of gold (Au) is formed on a  
30   pad 32 of the chip 31. The bump 36 has a bowl-shaped  
root portion and an end portion.

          An end of a gold wire is pressed on the pad  
32 and heated by a bonding tool so as to be joined to  
the pad. The gold wire is then removed. As a result,  
35   the bump 36 having a tear-drop shape is formed on the  
chip 31. The point end portion of the tear-drop  
shaped bump 36 is flattened. Conductive paste 38 is

1 then transferred to or printed on the surface of the  
flattened end portion of the bump 36. The conductive  
paste 38 is made of a thermosetting resin, such as the  
epoxy resin, in which silver (Ag) fillers are  
5 distributed. The conductive paste 38 transferred to  
the flattened end portion of the bump 36 is preheated  
so as to be in a semi-hardened state.

The surface of the chip 31 opposite to the  
surface on which a circuit is formed is held in  
10 position by the vacuum cavity 301, so that the chip 31  
is supported by the thermopressing head 30.

The board 33 is positioned and fixed on a  
table 40. A pad 34 which should be electrically  
connected to the bump 36 is formed on the board 33.  
15 The pad 34 is generally made of copper (Cu).

The adhesive 39 is applied to the surface of  
the board by using a dispenser or a printing  
technique. The adhesive 39 is made of thermosetting  
insulating resin including epoxy resin as the  
20 principal ingredient. The adhesive 39 has a heating  
characteristic by which liquidity of the adhesive is  
produced by an initial heating stage and then is  
gradually hardened with increasing temperature. Thus,  
since liquidity of the adhesive 39 applied to the  
25 whole surface of the board 33 is temporarily produced  
when the chip 32 is pressed on the board 33 by the  
thermopressing head 30, the adhesive 39 is prevented  
from flowing between the bump 36 of the chip 32 and  
the pad 34 of the board 33. The adhesive 39 may be  
30 applied to the surface of the board 33, except for the  
pad 34, by using the printing technique.

Fig. 4 is a timing chart indicating a time  
variation of the temperature and pressure in a  
thermopressing step. In Fig. 4, the axis of the  
35 abscissa indicates the time  $t$  and the axis of ordinate  
indicates the temperature  $T$  and the pressure  $P$ .

In a state where the chip 32 is set in the

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1 thermopressing head 30, the thermopressing head 30  
start to go down toward the table 40. The chip 32 is  
pressed on the board 33 by the thermopressing head 30.  
While the thermopressing head 30 is going down, the  
5 contact pressure PP of the bump 36 of the chip 32 to  
the pad 34 of the board is gradually increased from a  
time  $t_0$ .

In addition, the temperature TT of the  
adhesive 39 is gradually increased from room  
10 temperature RT. The reason is that the thermopressing  
head 30 is preheated by the heater 301 at a  
temperature sufficient to harden the adhesive 39.

While the temperature TT of the adhesive 39  
is gradually increased, liquidity of the adhesive 39  
15 is temporarily produced, that is, the viscosity of the  
adhesive is decreased. Thus, the adhesive 39 applied  
to the surface of the pad 34 is eliminated by the bump  
36 being pressed on the pad 34. As a result, the  
adhesive 39 will not be present between the bump 36  
20 and the pad 34.

While the thermopressing head 30 is moving  
further down, the contact pressure PP and the  
temperature TT of the adhesive 39 are increased. The  
thermopressing head 30 stops movement at a time  $t_1$  and  
25 is maintained at the position. At this time ( $t_1$ ), the  
contact pressure PP of the bump 36 to the pad 34 is  
maintained at a value PA shown in Fig. 5.

Fig. 5 shows a relationship between the  
contact pressure P and the electrical contact  
30 resistance R between the gold (Au) and the copper  
(Cu). In a region in which the contact pressure P is  
small, the electrical contact resistance is large.  
This region means that the connection between the gold  
and the copper is inferior. When the contact pressure  
35 P is increased and reaches a value equal to or greater  
than  $P_1$ , the electrical contact resistance rapidly  
decreases. This state means that the connection

The value PA at which the contact pressure PP of the bump 36 to the pad 34 should be controlled is set so as to be greater than the value P1. For example, it is preferable that the value PA is set at 30 grams. The value PA of the contact pressure PP is a value sufficient to provide plastic deformation to not only the end portion of the bump 36 but also the root portion of the bump 36. In addition, due to the contact pressure PP at the value PA, the pad 34 of the board 33 is subjected to plastic deformation by the bump 36.

Until the adhesive 39 is completely hardened, the thermopressing head 30 maintains the bump 36 in a state in which it is pressed on the pad 34 with a contact pressure PP of the value PA. At a time t4, after the adhesive 39 is completely hardened, the vacuum cavity 302 of the thermopressing head 30 is returned to atmospheric pressure so that the chip 32 is released from being supported by the thermopressing head 30. The thermopressing head 30 then starts to go up. Since the adhesive 39 is released from being heated by the thermopressing head 30, the temperature of the adhesive 39 is gradually decreased to the room temperature RT.

1 volume of the adhesive 39 is decreased, that is, the  
adhesive 39 is contracted. Thus, it is expected that  
the contact pressure is temporarily decreased  
immediately after the head 30 goes up and is separated  
5 from the chip 31. However, due to the contraction of  
the adhesive based on the decreasing temperature, a  
tension force is generated between the chip 31 and the  
board 33. As a result, the pressure force of the bump  
36 to the pad 34 returns to and can be maintained at  
10 the initial value PA.

Thus, in a state where the chip 31 is used  
inside electronic equipment, even if the adhesive 39  
is expanded and contracted based on the variation of  
the temperature, a decrease of the contact pressure of  
15 the bump 36 to the pad 34 can be limited to a minimum  
value. As a result, the reliability of the electrical  
connection of the chip 1 with the board 33 can be  
maintained.

The thermopressing head 30 from which the  
20 chip 32 has been separated is maintained at the  
hardening temperature of the adhesive. In the  
manufacturing process, the next chip is then supported  
on the thermopressing head 30 by the vacuum suction  
force.

#### 25 [MODIFICATIONS OF THE EMBODIMENT]

In the above embodiment, the conductive  
paste 38 covering the surface of the bump 36 is made  
of resin in which silver fillers are distributed.  
However, the conductive paste 38 may be made of  
30 anisotropic conductive adhesive in which capsules are  
distributed, each of the capsules being formed by  
covering silver articles with resin. In this case,  
the cover of each of the capsules is broken when the  
bump is pressed on the pad. The silver articles being  
35 positioned between the bump and the pad.

In addition, the electrical connection  
between the bump 36 and the pad mainly depends on the

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35           The transferring mechanism 53 has reel  
supporting blocks 70 and 71 installed at both sides of  
the gate-shaped block 51, reels 72 and 73 rotatably

1 supported by the reel supporting blocks 70 and 71,  
motors 74 and 75 rotating the reels 73 and 74, and a  
polyimide film sheet 76. The polyimide film sheet 76  
is wound on the reels 72 and 73 from both sides  
5 thereof so as to cross the gate-shaped block 51. A  
stainless steel plate 80 which is used as a jig is  
transferred by a conveyer and set on the table 40A.  
The polyimide film sheet 76 is located at a position  
(H1) slightly higher than the stainless steel plate 80  
10 set on the table 40A. The polyimide film sheet 76 is  
transferred in a direction A by rotation of each of  
the reels 72 and 73 respectively driven by the motors  
74 and 75.

The polyimide film sheet 76 has a relatively  
15 low thermal conductivity, such as 12 °C/cm. The  
thickness of the polyimide film sheet 76 is 25 μm. A  
heater 95 is mounted in the table 40A, so that the  
table 40A is heated at 80°C.

The raising and lowering mechanism 52 causes  
20 a guide 55 of a head supporting mechanism 54 to go up  
and down (vertically reciprocate).

A description will now be given of the chip  
mounting method using the chip mounting machine 50  
having the structure as described above.

25 First, the chip 10 is provisionally mounted  
on a flexible printed circuit board 81 which is fixed  
on the stainless steel plate 80, using a chip  
provisional mounting machine (not shown). As a  
result, a semi-finished product 90 in which the chip  
30 10 is provisionally mounted is formed. Next, the  
semi-finished product 90 is transferred to the chip  
mounting machine 50 by the conveyer and set therein.  
The head 30A presses the chip 10 on the flexible  
printed circuit board 81, with heat, so that the chip  
35 10 is completely mounted on the flexible printed  
circuit board 81.

Fig. 6 shows a state in which the semi-

1 finished product 90 transferred into the chip mounting  
machine 50 is positioned and set on the table 40A.  
The polyimide film sheet 76 is slightly over the chip  
10.

5 After it is recognized that the semi-  
finished product 90 is positioned and set on the table  
40A, the raising and lowering mechanism 52 is operated  
so that the head 30A moves downwardly. As enlarged  
and shown in Fig. 7, the head 30A presses the chip 10  
10 on the flexible circuit board 81 with application of  
heat. Between the head 30A and the chip 10, the  
polyimide film sheet 76 is set. After a predetermined  
time has elapsed, the head 30A is caused to move  
upwardly and separate from the chip 10.

15 When the raise and fall mechanism 50 is  
operated so that the head supporting mechanism 54  
moves downwardly and the head 30A is brought into  
contact with the chip 10, a spring 56 starts to be  
compressed. After this, the pressure of the head 30A  
20 to the chip 10 is increased by increasing the amount  
of compression of the spring 56. The raising and  
lowering mechanism 50 is operated until the amount of  
compression of the spring 56 reaches a predetermined  
value. An initial amount of compression of the spring  
25 56 is adjusted by a screw 57.

The pressing characteristic of the head 30A  
pressing the chip 10 is indicated by a line I in Fig.  
8. That is, the pressure of the head 30A to the chip  
10 is gradually increased starting from a time  $t_{10}$  as  
30 indicated by a line Ia and reaches a value PAa at a  
time  $t_{12}$ . After this, the pressure is maintained at  
the value PAa as indicated by a line Ib and is  
gradually decreased starting from a time  $t_{14}$  as  
indicated by a line Ic. The time  $t_{14}$  is a time at  
35 which a time period T1 that is needed to completely  
harden the adhesive 39 elapses from a time  $t_{13}$  at  
which the temperature of the adhesive 39 reaches the

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1     hardening temperature of 170°C.

          In addition, starting from a time at which  
the head 30A is brought into contact with the chip 10,  
the adhesive 39 is heated via the chip 10 until the  
5     temperature of the adhesive 39 reaches the hardening  
temperature of 170°C. The temperature of the adhesive  
39 varies as indicated by a line II in Fig. 8.

          If the polyimide film sheet 76 is not set  
between the head 30A and the chip 10 so that the head  
10     30A is in direct contact with the chip 10, the  
temperature of the adhesive 39 is rapidly increased as  
indicated by a line IIa in Fig. 8. A time period T2  
between the time  $t_{10}$  at which the head 30A is brought  
into contact with the chip 10 and a time  $t_{11}$  at which  
15     the temperature of the adhesive 39 reaches the  
hardening temperature of 170°C is relatively short.  
As a result, the time  $t_{12}$  at which the pressure of the  
head 30A to the chip 10 reaches the predetermined  
value PAa is after the time  $t_{11}$ . That is, before the  
20     pressure of the head 30A to the chip 10 reaches the  
predetermined value PAa, the adhesive starts to be  
hardened. Thus, some of the bumps 36 may be  
incompletely joined to the pads.

          On the other hand, according to the above  
25     method of the present invention, since the polyimide  
film sheet 76 is set between the head 30A and the chip  
10, the heat is transmitted through the polyimide film  
sheet 76 having a low thermal conductivity to the  
adhesive 39. As a result, the temperature of the  
30     adhesive 39 is increased, starting from the time  $t_{10}$   
at which the head 30A starts to press the chip 10, to  
the hardening temperature of 170°C as indicated by a  
line IIb. The line IIb is more gently sloping than  
the line IIa. A time period T3 between the time  $t_{10}$   
35     at which the head 30A starts to press the chip 10 and  
the time  $t_{13}$  at which the temperature of the adhesive  
39 reaches the hardening temperature of 170°C is

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1 greater than the time period T2 described above by T4.

Thus, the pressure of the head 30A to the  
chip 10 reaches the predetermined value PAa at the  
time  $t_{12}$ , before the time  $t_{13}$ . That is, before the  
5 adhesive 30 starts to be hardened, the pressure of the  
head 30A to the chip 10 reaches the predetermined  
value PAa. After the pressure reaches the  
predetermined value, the adhesive 39 starts to harden.  
As a result, the bump 36 is appropriately pressed on  
10 the pad so as to be securely joined to the pad. Thus,  
the chip 10 can be mounted on the board with a high  
reliability.

In addition, in Fig. 8, a line I1c indicates  
an increasing characteristic of the temperature of the  
15 adhesive 39 when the semi-finished product 90 is set  
on and heated by the table 40A.

Since the polyimide film sheet 76 has a heat  
resistance property, the polyimide film sheet 76 does  
not adhere to the head 30A and chip 10. The polyimide  
20 film sheet 76 is flexible, so that the surface of the  
chip 10 is not damaged.

After the head 10A moves upwardly and is  
separated from the chip 10, the motors 73 and 74 are  
driven so that the polyimide film sheet 76 is moved by  
25 one step. As a result, a part of the polyimide film  
sheet 76 which was set between the head 30A and the  
chip 10 is moved to the outside of the gate-shaped  
block 51 and a new part of the polyimide film sheet 76  
which has not yet been used is fed into a space in the  
30 gate-shaped block 51. The new part of the polyimide  
film sheet 76 is used for the next semi-finished  
product 90 so as to be set between the head 30A and  
the chip 10.

A polyester film sheet or a silicon film  
35 sheet may be substituted for the polyimide film sheet  
76.

Instead of setting material having a low

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1 thermal conductivity, such as the polyimide film sheet  
76, between the head 30A and the chip 10, the head 30A  
may be temporarily cooled immediately before the head  
30A is brought into contact with the chip 10.

5 If the heater in the head 30A is turned on  
after the head 30 presses the chip 10, the adhesive 39  
can start to be hardened after the pressure of the  
head 30A to the chip 10 reaches the predetermined  
value PAa without the polyimide film sheet 76.

10 However, according to this method, a time period  
required for mounting the chip is increased, so that  
production deteriorates. From a viewpoint of  
production, the method according to the above  
embodiment of the present invention is preferable.

15 The present invention is not limited to the  
aforementioned embodiments, and other variations and  
modifications may be made without departing from the  
scope of the claimed invention.

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